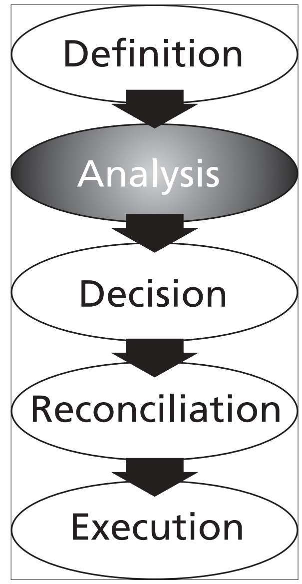
CHAPTER 4

ANALYSIS CONCEPTS: COST



What is a cynic? A man who knows the price of everything and the value of nothing.

-Oscar Wilde, *Lady Windemere's Fan,* 1892

COST IS ALMOST ALWAYS A CRITICAL FACTOR in defense decision making. Whether we are deciding on a new force mix, looking for a solution to a mission area deficiency, or choosing among policy options, someone during the decision making process will want to know the cost of our proposed solution. Selecting the best alternative and ultimately the success of our program or policy may well hinge on our ability to measure cost accurately and satisfactorily.

When we choose wisely, cost is on the opposite side of the coin from effectiveness. If we want to improve effectiveness, we will increase cost. If we cut cost, we reduce effectiveness. While we often discuss each separately, sometimes in isolation, they are inextricably related. The tension between cost and effectiveness is one of the reasons our defense resource allocation process is based on advocacy and adjudication: we fully expect the operators to demand the highest levels of effectiveness while the managers try to spread limited resources among a mix of programs to provide the best overall capability to all the operators, present and future. Indeed, this is the crux of the argument between supporters of the V-22 and those who wish to cancel it: is the greater effectiveness worth the additional cost—including the lost opportunity to fund other programs? (See Dr. Chu's testimony in Appendix 3.)

Selecting Measures of Cost

Measures of cost are a subset of the criteria we use to compare alternatives. Just as with measures of effectiveness (and all other criteria), we should have the decision maker approve our MOCs before we begin the analysis. There are two guidelines we follow when selecting measures of cost in addition to those for other criteria:

- Future Costs
- Standard Metrics

In addition to the immediate costs of alternatives, the cost portion of the analysis should also focus on costs yet to be born. We should isolate near-term costs and display them for the next budget year and, with only slightly less precision, up to the end of the next Future-Years

Defense Program (five or six years distant). In almost all cases, our analysis should consider life cycle cost in constant dollars.

We may include costs not measured in dollars, such as manpower, material resources, etc., as the situation warrants. We should use the same yardstick for each of the alternatives to permit easy, side-by-side comparisons. This means we must specify the type of cost information we require when we issue a request for proposals; respondents naturally tend to emphasize the type of cost most favorable to themselves and, left to their own devices, they may not provide the same types of costs as one another. We test our selection of MOCs, individually and as a set, using the concepts of validity, reliability, and practicality that we discussed in Chapter 3.

For an executive decision maker in the Department of Defense, the issue is not the mechanics of calculating costs; the point is whether the measures of cost proposed by the analyst fit the problem. Senior leaders in DoD must also be prepared to provide guidance to the analyst with respect to how they want costs estimated, lest the cost information they receive not support rational decision making.

Types of Cost

Cost is what we give up for what we want; our opportunities forgone. Money is the most common way to measure costs, but other methods are often more appropriate for force planning decisions. Ships burn fuel, expend ordnance, and need people to man them. Analysts can turn all these into dollars, but in combat the resources themselves are more direct and appropriate measures of cost. Many times we need to recognize that these other kinds of costs factor into peacetime force planning as well. The space a ship takes up alongside a pier or the wear and tear on an aircraft-launching catapult are costs that dollars alone cannot describe accurately. Cost, in addition to resources consumed, also represents opportunities lost by the choice of this use of money.

Analysts add modifiers to specify a multitude of specialized types of cost. The Navy's *Economic Analysis Handbook* alone has three pages of cost definitions. As executive decision makers, we need to understand the fundamentals of cost terminology in order to compare alternatives accurately and to communicate clearly among ourselves and with analysts. Most of our discussion of types of costs concerns procurement options, but many of these same concepts apply to policy alternatives.

We must be certain that the contractors, the analysts, and we ourselves use the same terms and define cost the same way. During a competition among American companies for a recent foreign military sale, the purchasing nation wanted a tactical aircraft that could deliver infrared-guided, air-to-ground weapons. One aircraft had this guidance capability built into the fuselage and nose of the aircraft. The other aircraft used a detachable pod carried under the wing. Both manufacturers' aircraft therefore met the requirement. The decision makers sought to compare the two alternatives' flyaway costs. The latter aircraft's manufacturer did not include the price of the pod in its proposal because of the loose way the purchaser defined cost, significantly (and knowingly) decreasing the apparent cost of that aircraft.

RELEVANT COST

One of the most difficult and important concepts of cost is differentiating between costs that result from a decision and those that do not. Relevant costs, as we define them for this course, are *forthcoming* costs that distinguish among the alternatives in our decision. They include the costs common to all the alternatives and the unique costs of each. While all costs are relevant to one decision or another, we tend to focus on costs that concern our organization. The concept of relevant costs is akin to that of validity—our need to ensure we measure the things that matter.

For example, the Navy programmers who estimate the cost of a new aircraft carrier usually exclude the cost of the air wing and surface ship escorts from the cost of the ship, even though the carrier cannot operate effectively without either. The cost of the aircraft and escorts are irrelevant to the cost of the aircraft carrier—so long as they do not increase or decrease because of our decision. If, however, we pick a new aircraft carrier design that requires five more aircraft than another design, the extra cost of the five aircraft is a result of our decision, and thus relevant. Before discarding any cost as irrelevant, we must be absolutely certain that our decision is not concerned with it.

SUNK COST

Irrecoverable expenditures we have already made are Sunk Costs. They are irrelevant to our decision because we cannot recoup them no matter how hard we try. Sunk costs are useful (in a historical sense) to determine the actual cost of an activity or program and help us predict the overall cost of new proposals. They are also very important for legal and accounting purposes, but not for decision making per se.

Sunk costs, in and of themselves, should have no bearing on an economic analysis or a decision concerning the future expenditure of resources. One problem with sunk costs is that we are not perfect economic people. We have a natural tendency to see value in money already spent, and, especially, in our effort already expended. We do not want to consider the time we devoted to a project as wasted, so we are inclined to continue programs and policies after we have spent money on them, even when the current course of action is no longer the best alternative. This situation occurs most often when the original need for a program has diminished or disappeared. For example, the decline of the Russian Navy as a blue water competitor with the U.S. Navy has led to major changes in U.S. naval strategy and doctrine and thereby the restructuring of many programs. Some programs have slowed down and others have been canceled despite the resistance of their well-intentioned program managers and community sponsors. Executive decision makers made their force planning choices about which programs to continue based on the requirements, urgency, and future costs of the alternatives. Pleas based solely on sunk cost rightly fell on deaf ears.

Programs that become more advanced, however, often gain a tangible advantage over competing alternatives as their sunk cost accrues. Since we focus on future cost, a new alternative, with all its research and development costs before it, is unlikely to be competitive from a cost standpoint against a program that is already underway. That is why the most acrimonious debates in defense resource allocation occur when we decide which programs to start.

GETTING THE CAMEL'S NOSE UNDER THE TENT: THE F-22 RAPTOR

Advocates know that the money spent before a system is operational generates program inertia, which makes a funded alternative increasingly preferable. As more of its cost becomes irrecoverable, other options become less competitive on the basis of cost alone. A classic example of this is the ongoing debate over the Air Force's acquisition of Lockheed-Martin's F-22 Raptor.

There has been nearly universal agreement since 1985 that the Air Force must re-place its fleet of F-15 air superiority fighters because of their advancing age. In the early 1990s, opponents of the F-22 argued that its cost per aircraft ($160-180M) was prohibitively expensive and deliberately underestimated by its proponents at $85M. The contrarians preferred continuing the production line of the older F-15 at about $45M per aircraft and cited a number of studies that the F-22, in conjunction with other tactical aviation plans, was unaffordable. The Air Force stressed the (undisputed) greater capabilities of the F-22 and determined they would find a way to afford it.

The Air Force focused largely on lesser near-term costs and built program inertia, despite Congressional concerns about cost. In 1997, Congress placed a $37.9B cost cap for procuring 339 fighters. That cap caused several major adjustments to the Acquisition Program Baseline, including December 2000's reduction from 86 to 73 aircraft in Low Rate Initial Production (LRIP) in hopes that full production aircraft would be significantly less costly.[1] In 1999 Chairman Jerry Lewis led the House Appropriations Committee to remove procurement funds for the F-22 from the FY00 Defense Appropriations Bill. The compromise that restored the funding required the F-22 to pass certain exit test criteria by 21 December 2000; however, Lockheed-Martin did not complete the required avionics and fatigue testing portions until 5 February 2001, in part due to bad weather and a labor strike.

In spite of this, Congress allowed the Pentagon to release $350M to keep suppliers and preparations for production going through 31 March 2001. The F-22 passed the Defense Acquisition Board's Milestone III on 6 February 2001. On 15 August 2001, the Defense Acquisition Board authorized LRIP of ten F-22s. However, its increasing cost mandated that the total number of airframes would shrink from 339 to 295. Based on usage of the term *cost*, both sides were vindicated: the *average* cost is now up to $173 million. However, the *variable* cost of the fighter is $84 million. The average cost, of course, included sunk costs of upwards to $20 billion in research, development, test, and evaluation funds.

OPPORTUNITY COST

Limited resources create opportunity costs; they are the things we forgo by choosing to attain something else. With unlimited resources, we have no opportunity costs because we can obtain all we desire; for DoD this would mean an unbounded force structure with all our programs and policies funded at 100 percent. In a world of constrained resources we must make choices: we fund more modernization than infrastructure; we deploy forces here instead of there; we fund recruiting incentives at the expense of retention bonuses; etc.

Decision makers in business measure opportunity cost most often in dollars, as profit made or lost. Imagine there is a factory that currently makes a product that generates profits of $100,000 every year. The corporate owners are considering retooling this factory to make a new product. The opportunity cost of surrendering the first use of the factory to make the current product should be added to all the other costs of beginning to make the new product; that $100,000 is forgone revenue and would otherwise have been added to the firm's profits. It is a cost as legitimate as all others are. No accountant records it because it is an event that did not happen, but executives must know and consider it.

In DoD, some opportunity costs are difficult to express in dollars, but we consider opportunity cost in every decision involving spending. If the Marine Corps decides to spend one million

1. Tony Capaccio, "U.S. Air Force To Delay Some F-22 Buys To Control Rising Costs," Bloomberg.com, 18 Dec., 2000

dollars for new trucks, and the next best use for those funds is new mobile field kitchens and power generators for field headquarters, we assume some analysis occurred to pick one option over the other. Without profit as a measure of return on investment, what measure did the Marine Corps apply? Almost certainly, something less tangible called value or utility, and the decision was made based on the most benefit to the service goal of winning battles. Programmers face these decisions daily; they know the operators want the best system possible but that the increased effectiveness must come at the cost—and therefore effectiveness (or even existence) of other programs.

EXTERNAL COST

Costs beyond the problem's boundaries are external to the analysis. Because they occur outside our organization they are usually irrelevant to our decision. In many cases, excluding a particular cost means that the cost, in reality, is now included in another organization's budget—we effectively transfer it outside our organization. The other organization may be a private company, another group within DoD but outside our chain of command, or another branch of government. If we do not transfer the cost very far, it may reappear later in the decision, when our organizations fall under a common superior. Our decision to exclude and thus transfer cost is a spillover effect onto those other organizations and they may object to the transfer when we reconcile the decision. For example, when the Public Works Department of a facility increases its utility surcharges to tenant commands to cover its increased costs, it is transferring the costs to the tenants who are usually outside its chain of command.

We should indicate to the decision maker where we assume or impose cost transfers. For example, when the Joint Staff and a unified commander consider the cost of a security assistance program for another nation, they consider the cost to DoD. Many other costs for the program will be borne by the Department of State, but those costs are not relevant to our internal DoD decisions. We may encounter the effects of the costs imposed on the State Department later as we reconcile our proposal, but we do not use them to consider the alternatives in our decision.

FIXED, VARIABLE, AND AVERAGE COSTS

Fixed costs are expenses that we incur whenever we initiate a course of action. They occur regardless of the intensity of the action or the number of items we procure; for example, research and development costs are fixed costs. Variable costs change depending on how we execute our program, particularly as we alter total purchase quantity or annual production rate. Fixed costs are tied to factors unlikely to change, such as the size and cost of the daily operation of the production facility. Variable costs change conditionally, as with adjustments to the size of the work force or the price of materials.

Period costs are fixed costs that accumulate over time, regardless of the amount of product or service purchased. They are primarily wages and facilities-related costs that may conceal inefficiencies we can eliminate by adjusting the production rate, thereby reducing the total cost. For example, we may have a labor force that is working below its capacity that cannot be reduced because of the distribution of skills required to produce each item. However, if we have funds to buy more materials and we can accept earlier deliveries (which may mean training more DoD operators in the near term—spillover costs), the contractor could produce more systems in the time that the labor force is being paid. We reduce the total time to produce all the systems and save period costs by having fewer periods.

$$\text{AVERAGE COST} = \frac{\text{TOTAL COST}}{\text{TOTAL QUANTITY}}$$

$$\text{TOTAL COST} = \text{FIXED COST} + \text{VARIABLE COST}$$

IF THE NAVY BUYS...

12 PATROL CRAFT		6 PATROL CRAFT	
FIXED COST		*FIXED COST*	
R&D	$1.5M	R&D	$1.5M
FACILITIES	$12M	FACILITIES	$12M
ANNUAL OVERHEAD	$2.5M	ANNUAL OVERHEAD	$2.5M
	$16M		$16M
VARIABLE COST		*VARIABLE COST*	
MATERIALS	$24M	MATERIALS	$12M
LABOR	$16M	LABOR	$8M
	$40M		$20M
TOTAL COST	$56M	*TOTAL COST*	$36M
AVERAGE COST	$4.7M/CRAFT	*AVERAGE COST*	$6.0M/CRAFT

Figure 4-1. Fixed, Variable, and Average Costs of Patrol Craft.

Variable costs change with the ebb and flow of the production quantities and scheduled deliveries. A particular type of variable cost is Incremental Cost: the added cost of purchasing one more of something, e.g., adding one more destroyer to a program or one more student to each seminar. The fixed costs remain the same, but the additional unit requires more resources: more labor and materials for the ship and more administration, counseling, and grading for the student.

Generally, variable costs decrease per unit as purchase quantity increases, up to some threshold, e.g., the maximum fabrication capacity of a facility. These result in volume discounts where the manufacturer lowers his price per unit to reflect the wider distribution of fixed costs among more units. Prices may jump upward again if the contractor opens a new production facility (incurring new fixed costs) and begin declining again as production increases.

Average cost is the total of fixed and variable life cycle costs divided by the number of units we procure.[2] Let us suppose the Navy plans to buy new patrol craft for its units assigned to the U.S. Special Operations Command. Regardless of how many craft the Navy purchases, there will be unchanging fixed costs associated with the program: the design work, setting up an assembly area, signing and managing contracts, etc. These are summarized in figure 4-1 as fixed costs. Because of these fixed costs, reducing the production quantity from 12 to six boats, as shown in figure 4-1, increases average cost. The total program cost is reduced, saving money, but the average price per boat grows higher.

Why is this important? With the high cost of modern weapons systems, many critics of the Pentagon cite average prices in their argument. If we cut a program and reduce its purchase quantity, we will not recoup as savings the average price of the equipment forgone, just as dropping from 12 to six patrol craft did not halve the cost of the program in figure 4-1.

	FY 02	FY 03	FY 04	FY 05	FY 06	Total Cost	Cost per Craft
3 Craft per year	$13.5M	$12.5M	$12.5M	$12.5M	$12.5M	$63.5M	$5.3M
6 Craft per year	$13.5M	$22.5M	$22.5M	0	0	$58.5M	$4.9M

Table 4-1. Stretching Out Procurement.

Reducing the production rate, thus stretching out a procurement program over more time, is a common technique to reduce near-term cost. However, the overall effect of stretching a program is to increase the total cost of the program and the average cost of each system because we

2. Related to average cost, we often see aircraft described in terms of Fly-Away Costs and Procurement Costs. Fly-away costs include only research and development and narrowly defined production costs. Procurement costs include fly-away costs plus initial contractor support of production models, contractor training of service personnel, and an initial set of spare parts for each system.

must bear the fixed costs longer. Returning to the patrol craft example, instead of buying them all in one year, as in figure 4-1, we will consider two cost streams for purchasing 12 patrol craft. The first uses a production rate of three boats per year for four years and the second six boats per year for two years. Table 4-1 shows the start-up costs (research and development and facilities set-up) occurring in FY02 with production beginning in FY 03. The costs shown in FY03 through FY06 are the annual overhead of the boatyard plus labor and materials for each boat. By stretching out the boat fabrication over four years, instead of two, we increase the total cost of the 12-boat program by $5M or 8.5 percent.

Industrial fabrication has a phenomenon called the Rate Effect. It describes the way costs change as the production rate shifts away from full capacity and explains why cost reductions do not decrease linearly with cuts in the production rate. As we discussed earlier, only the variable costs are eliminated while the fixed costs remain. If we order fewer missiles than the contractor had anticipated, the contractor will not be able to proportionately reduce all costs and DoD will pay more per unit than we anticipated. This is why stretching out programs to reduce near-term cost not only increases average cost and frustrates planners, it also creates instantaneous procurement and life cycle cost overruns.

Why would we ever stretch out a program? Sometimes the pressure on the near-term budget is so great that we must reduce production rate to keep the program alive; the only other choices are to cancel it or another vital program outright because the money simply is not available for full production. The closer we get to the budget year, the more "real" the money becomes and the more necessary it is that we refine spending forecasts and push spending further into the future to balance the books in the near-term.

The cumulative effect of stretching out programs, as DoD has done over the past ten years, is extremely deleterious. Because fewer replacement vehicles and systems reach the operating forces, the average age of equipment increases. Older equipment requires more maintenance to stay ready, drawing resources away from modernization (and other) accounts. The effect is cumulative, too. As we delay purchases year after year, the total number of new procurements we need increases; the new deferrals add to the old, and now we face a department-wide procurement bow wave that analysts estimate will cost an additional $80-120B per year to maintain DoD's current force structure and replacements for aging weapons.

In complex decisions, the determination of which costs are fixed, which are variable, and the correct construction of average cost are critical to thorough economic analysis. Separating fixed and variable cost is very important when we make decisions about incremental changes to programs or policies. Just as DoD cannot save the average cost per mile by steaming a ship one less mile (we save only a part of variable cost by conserving the fuel), we cannot save the average cost of educating a Midshipman by decreasing the Naval Academy's enrollment by one.

LIFE CYCLE COST

As shown in figure 4-2, life cycle cost includes all the costs associated with a system from conception to disposal or deactivation. Note that the segments in the figure are additive (this is often called a sand chart) and that the top-most boundary is the combined cost for that time period. Many executive decision makers focus on procurement cost because they assume that it represents the biggest share of life cycle cost. Historically, however, the largest part of life cycle cost is for operations and maintenance during the service life of the equipment. For example, 80 percent of the life cycle cost of an average Navy ship goes toward operations and maintenance after it joins the fleet (and 50 percent of this cost is, in turn, for personnel).[3] For almost all procurement option comparisons, life cycle costs are among the most important criteria for defense decision makers. The major components of DoD life cycle cost are:

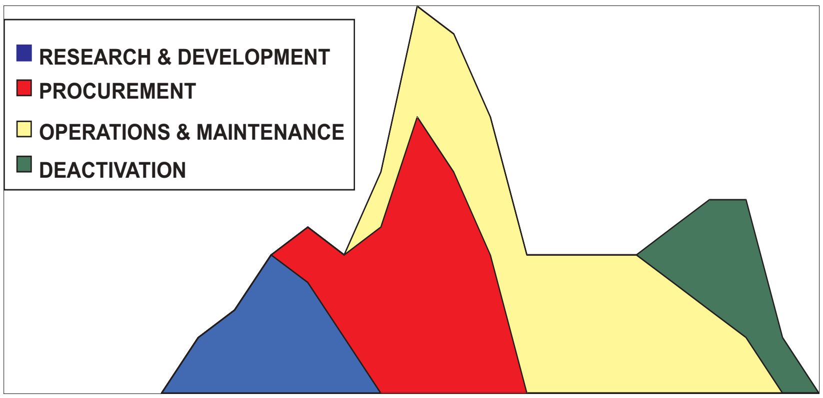


Figure 4-2. Life Cycle Cost.

- ***Research and Development Costs*** (3600 money[4]): concept and feasibility studies; engineering design; test, and evaluation of engineering models; and associated management functions.
- ***Procurement Costs*** (3080 money): industrial engineering, facility construction, process development, materials, manufacturing, production operations, quality control, and initial logistics support requirements.
- ***Operation and Maintenance Costs*** (3400 money): training DoD personnel; consumable supplies such as fuel, spare parts and other sustaining logistic support; intermediate and advanced maintenance, and replacements distribution.
- ***Deactivation Costs***: demilitarization, disposal of non-repairable items, system retirement, material recycling, and related logistic support requirements.

TOTAL OWNERSHIP COST

Beyond life cycle cost, DoD has embarked on a new attempt to capture during acquisition planning all the costs associated with hardware, i.e., the transfer costs borne by the users and owners of the equipment procured by the acquisition system. The DoD definition of Total Ownership Cost is: *Costs to research, develop, acquire, own, operate, and dispose of weapon and support systems; other equipment and real property; the costs to recruit, train, retain, separate, and otherwise support military and civilian personnel; and all other [related] costs of business operations of the DoD.*

Total ownership cost includes all aspects of life cycle cost and more; in addition to direct personnel-related costs (crews and their training), it includes the cost of the supporting infrastructure that plans, manages, and executes the program over its full life, as well as the cost of common support items and systems that a service incurs because of the introduction of the system. The Navy is using this methodology with 20 test programs in place, including some of our largest weapons systems acquisition programs. By exhaustively including second order costs and beyond, the Department of Defense is acknowledging that the greatest costs associated with many programs occur after the system becomes operational, that those costs should be considered when choosing among alternatives, and that therefore we need to find a way to capture them in advance to support analysis.

This means many costs we previously counted as external to a program are now internal, e.g., the educational and recruiting costs of the share of boot-camp recruits who are destined to work on a particular system. Program managers reduce total ownership cost through their tra-

3. J. Talbot Manvel, Jr. , "The Next-Generation Aircraft Carrier," *United States Naval Institute Proceedings*, Jun. 2000: 70.
4. Programmers in the Pentagon use these shorthand codes to refer back to budget rules that restrict how funds may be expended, e.g., "We will not be able to obligate all our 3600 money for this program by the end of the fiscal year."

ditional attempts to reduce life cycle cost for their systems and now by reducing demands on the rest of the Navy. Thus, manning reductions in the crew and support staff of maintainers and logisticians has become a priority for the program manager whereas previously he or she focused almost exclusively on the cost of the hardware and perhaps spare parts. The program manager may decide to incorporate more expensive—in terms of procurement dollars—labor saving devices to reduce crew-manning requirements to reduce total ownership cost; under traditional acquisition management philosophy, he or she would be tempted to opt for the less expensive equipment to keep the procurement cost lower. Similarly, training commands that educate technicians are examining their courses to reduce the time to get the sailor to the job, lowering the average "cost" of a sailor and thereby the total ownership cost for the system.

Implementing total ownership cost concepts will not be easy. The Air Force owns and manages all of DoD's space assets, but all of the services use them. Should the Air Force charge user fees to the other services, similar to Working Capital Fund arrangements on bases, to reduce its total ownership cost? Because total ownership cost includes "linked-indirect" costs, i.e., those that are generated as a result of introducing and supporting a system, but which cannot be directly associated with one specific usage or program, where do we draw the line and prevent system-owning commands from charging expenses to a user that the owning command would incur anyway? Do we assess the average cost or the incremental cost of the manpower associated with the support system in the user system's total ownership cost? Should we allow the Air Force to include part of the cost of manpower recruiting, basic training of the technicians (and the recruiters), and electronics training common to all space systems in its user fees? Clearly, we would exclude the costs of Air Force marching bands and fighter squadrons, but there are many gray areas in between.

Three notions appear from the idea of total ownership cost. First, as we discussed above, although the concept of total ownership cost is clear, calculating, measuring, and centralizing these costs is difficult, raising a large practicality issue. Second, our economic analysis, particularly analyses of alternatives, could be hampered by simplified or uneven total ownership cost efforts. A single-seat attack aircraft halves the personnel costs of air-crews compared to a two-seat version of that system. Will cost predominate in this case at the expense of effectiveness? Third, many systems are themselves largely dependent upon other systems, or would not even exist without them. For example, how should we assess the total ownership cost of the Joint Stand-Off Weapon, an air-delivered Global Positioning System (GPS)-guided weapon? This weapon could not function without GPS; therefore its total ownership cost should include part of the cost of GPS. On the other hand, we would have established GPS regardless of the standoff weapon, so why should it be taxed for something that would have happened anyway? What is the fair apportionment of total ownership cost for each user of GPS?

Cost, Effectiveness, and Schedule

Cost, effectiveness, and schedule are familiar criteria in defense decisions. While time can be thought of as a cost, we can also think of it as a performance factor: we would almost always rather have a capability sooner than later. Whether we treat schedules as a subset of cost or effectiveness, or as their own criteria, depends upon the decision. When we construct a schedule of the outlays for a program—a cash flow—we are combining time and money. When we construct deadlines for achieving a level of performance, we are combining time and effectiveness.

How quickly we can execute our decision is directly linked to when money is available; funding is a prerequisite for executing the schedule. Sometimes, if we obligate more money faster, we can accelerate research and development, the procurement rate, or the date of initial operational capability. Technology may also constrain scheduling, as is happening now with national missile defense; we have money available but cannot spend it wisely until we overcome several technical hurdles.

Types of Dollars

To help us evaluate alternatives, the analyst may include costs based on several different kinds of dollars. The types of dollars we primarily use in defense decision making are current dollars and constant dollars. We show them in figure 4-3 and will explain how we convert between them.

CURRENT DOLLARS

We spend current dollars. As we budget for the future, we express our planned spending in the dollars of the year when we intend to make the outlay. We also know that most costs rise over time due to inflation, which reduces the value of today's dollar. The actual purchase price we will pay in the future (the amount we will write the check for), increased from today's price because of inflation, is measured in current or then-year dollars (they will be current dollars *then*). Thus, if an item costs $100 in 2002 current dollars and there is a ten percent annual increase in prices (inflation), we will pay $110 one-year later using year 2003 current (then-year) dollars.

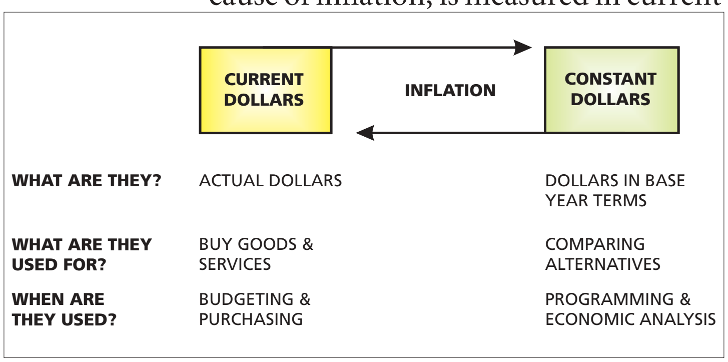


Figure 4-3. Types of Dollars.

All our authorizations and appropriations from Congress, including the Defense Authorization Bill and Defense Appropriation Bills, are expressed in current dollars because they represent the actual money we will spend. Likewise, the dollar amounts in the Executive Branch's federal budget are expressed in current dollars, as are those in the Future-Years Defense Program. Again, current dollars are the only dollars that are actually spent for goods and services.

Imagine that during the 2002 Defense budget preparation the Navy will request two identical ships, one to be built in 2002 and the other in 2005. Using a five percent price inflation rate,[5] a new ship projected to cost $850 million in 2002 (2002 current dollars) would cost $984 million in 2005 (2005 current or then-year dollars). Since the ships are identical, the increased cost is due to the rise in prices for goods and services alone: the effects of inflation from 2002 to 2005. We can use current dollars to compare values easily within the same fiscal year, but, because of inflation, current dollars are not useful for directly comparing and evaluating alternatives in different years. Is the 2005 ship worth more than the 2002 ship because it cost more? Obviously not, so we need a methodology to account for inflation so that we can examine the cost of alternatives across different years.

CONSTANT DOLLARS

There are many occasions when we wish to compare the price of equipment and services bought during different years. Inflation makes impossible an accurate comparison of worth, based on

5. DoD uses inflation rates provided by the President's Office of Management and Budget. If Congress disagrees, they may use their own inflation rate from the Congressional Budget Office and re-calculate DoD's math if they decide to authorize and appropriate the ships.

current dollars alone, because we must account for the inevitable erosion of purchasing power. Constant dollars are funds from different years that have been adjusted for the effects of inflation and benchmarked to a base year.[6] The base year may be any year we prefer—often it is the next fiscal year—the fundamental requirement is that we use the same base year for all our calculations. We can convert then-year dollars from a base year in either direction, forecasting costs into the future or reflecting into the past to make direct comparisons.

For example, suppose we desire to compare the price of a ship the Navy purchased in 2002 for $900 million (2002 current dollars) to an identical ship purchased in 1996 for $650 million (1996 current dollars) to see if there was a price increase beyond inflation. First, we determine there was a constant five percent inflation rate between 1996 and 2002, then we calculate the cost of the 2002 ship as if we had bought in 1996, our base year. The year 2002 ship cost $672 million in 1996 constant dollars. By converting costs to constant dollars, the analyst can say the true increase in price for the new ship is $22 million in 1996 constant dollars, not the apparent $250 million. Constant dollars provide a common measure we can use to compare alternatives independent of inflation so long as we calculate the costs of the alternatives using the same base year.

CASH FLOWS

When DoD buys a new weapon system or implements a new policy, we usually incur costs and make outlays over a multi-year period. We display our anticipated annual outlays in a table with years and budget amounts to create a picture of the program or policy's cost stream or cash flow. Cash flows facilitate comparisons among alternatives and are crucial as we prepare programs and budgets in the formal resources allocation process. Once we select a program alternative, its cash flow gets translated into budget lines as part of the Acquisition Program Baseline. Policy alternatives get funded similarly, after their cash flows are converted into the various types of funds Congress appropriates and DoD disburses.

Cash flows are different from life cycle cost because they describe only relevant (forthcoming) costs. For example, the Joint Strike Fighter Program Office authorized two consortia to produce flying prototype aircraft to compete for the production contract. The program office will compare the aircraft on the basis of cost and effectiveness; for the cost analysis, they will undoubtedly display cost as cash flows: how much it will cost to complete the program each year for the production run and service life of each alternative. They will also likely request cash flows for different production rates and total purchases.

Historically, life cycle cost or average cost may be of interest to some decision participants, but many of the costs of both prototype Joint Strike Fighter aircraft, such as research and development, are already sunk, and therefore irrecoverable. Based on our earlier discussion, they should not play into DoD's decision on how to proceed. Executive decision makers need to focus their attention on cash flows of relevant costs, those they will have to budget in the future. As sensible as this seems, for many decisions the senior executive in DoD must specifically request information on cash flows. Many analysts use older techniques and contractors prefer to present their options in the most favorable light—which may *not* be displayed as a cash flow.

6. The calculation is the same as for compounding interest: Constant Year \$ = Base Year \$ * (1 + i)n where i is the inflation rate and n is the number of years distant from the base year.

As we begin analysis of a new weapon system, we should have the analyst or contractor estimate the cash flow as a function of the production schedule and purchase quantity. Contractor costs are extremely sensitive to production rate adjustments, especially for major systems like ships and aircraft. Generally, as production rate decreases and delivery is delayed, fixed costs per unit rise. If the total procurement quantity is reduced, average unit costs again rise. Because we know that deviation from either the total number purchased or the planned production rate causes changes in cash flow, we may ask contractors for estimated cash flows for several purchasing strategies.

Contracting Strategies

Congress and the Department of Defense have long sought to minimize and prevent cost increases in procurement programs. There is a fundamental tension at work in defense acquisition. Contractors value stability—unchanging requirements (effectiveness), guaranteed production rates or purchase quantities, and predictable cash flows (outlays). The Federal Government, however, wants flexibility to modify a program—to improve effectiveness (often as the result of new technology) to give operators the best possible equipment and to change production rate or quantity to save near-term budget dollars. In business, one must pay for that flexibility by paying more money to the contractor in profits to reward his (and his shareholders) assumption of higher risk under more volatile circumstances.

The most common type of contract for new major weapons systems is "cost-plus" wherein the manufacturer bills the government for the actual cost of work done, plus a percentage of cost or fixed fee that is his profit. The need for oversight is obvious; the contractor has no incentive to reduce costs and in some cases incentives to increase them or at least charge as much shared corporation overhead as possible against a cost-plus contract. To provide an incentive for the contractor to reduce cost, DoD has begun to include performance incentives in its cost-plus contracts. The manufacturer receives bonuses for reaching program milestones ahead of schedule or for reducing costs below programmed levels. To increase oversight of these kinds of programs, each service has created corps of acquisition professionals who, when they are not assigned to their branch or warfare community, specialize in acquisition management. The DoD Inspector General, the General Accounting Office, and the Congressional Budget Office also exist, at least in part, to oversee government contract execution because of our stewardship concerns over acquisition programs.

Historically, DoD has made several major attempts to implement cost-saving strategies. In the 1970s, the Navy issued several "design-to-price" contracts for major weapon systems, including the Perry-class frigate. The key concept was to cap the production cost of each ship and thereby limit cost growth by making it fiscally impossible to add new equipment without removing something else; the new gear would have to compete for dollars and space within the existing design. The result was a ship that saw its capabilities progressively reduced, eaten away by inflation. For example, the fire control radars had less range than other missile and gun-equipped escorts because of their low power output. The fire control system was an off-the-shelf Dutch system, so the U.S. Navy had little flexibility to change its characteristics and even if it could, another capability would be lost to compensate. Predictably, the Surface Warfare community was dissatisfied with the result. Eventually, the ships were upgraded in a series of costly overhauls and design changes and they became effective escorts.[7] Operators' reactions to other design-to-price procurements were similar and the practice is currently disused—except, in a sense, when Congress places budget caps on programs like the F-22.

The second cost control method the government has attempted is to forgo flexibility by issuing fixed price contracts. In this case, DoD agrees to lock in requirements (specifications) and quantities that enable the manufacturer to predict his incoming cash flow and production requirements with near certainty. DoD uses fixed price contacts widely with bulk purchases and for simpler equipment. A government contracting office issues a request for proposals with quantities and specifications and the lowest qualified bidder wins the contract.

Secretary of the Navy John Lehman sought to extend this type of contract to major weapon systems in the 1990s. This, too, had unforeseen consequences. For major weapon systems, like nuclear-powered submarines, the specifications were written loosely enough to allow for the injection of new technology without renegotiating the contract. High-profile court cases resulted wherein the contractors alleged the Navy effectively changed requirements while refusing to compensate the contractor for the new costs thus incurred. As a result, many manufacturers will only accept fixed price contracts for mature programs, e.g., buying additional ships and aircraft that are already in production.

An important way DoD reduces the cost of a procurement option is to enter into a multi-year contract with the manufacturer that effectively locks in our cash flow for the period of the contract. Normally, DoD signs one-year contracts with a company to purchase a fixed quantity of goods or services. In some cases, we award the contract to different companies each year after competitive bidding. This process creates significant risk and uncertainty for the manufacturers as they try to predict their future sales and production level requirements. Multi-year contracts provide stability for the manufacturer by easing his uncertainty about incoming revenue and its contribution to his cash flow and by facilitating his ability to predict cost. If the manufacturer knows in advance what his long-term sales volume will be, he or she can plan fixed cost investments in production capacity (including the labor force) that approach optimal production rates to counter the rate effect.

With multi-year contracts, the manufacturer can enter into smarter business arrangements with sub-contractors for higher quantities of material or longer-term agreements for just-in-time delivery. The end result is a lower total cost for production that the manufacturer passes on, at least in part, to DoD. If the Pentagon cancels the contract before completion, there are usually penalties it pays to reimburse the manufacturer for his up-front investments to support the contract. The principal advantage of multi-year contracts is better program stability. Their disadvantage to DoD is the loss in programming and budgeting flexibility from year to year. The disadvantage to Congress is a perceived loss of control over funding, or at least a reduced opportunity to debate the need for the program in successive years.

For the F-22 program, the Air Force is trying two new incentive programs to create cost reductions to stay within Congress-mandated spending caps, without reducing from 295 the overall number of aircraft they purchase. By spending $475M over the next five years, the Air Force anticipates avoiding the currently projected $2B program overrun, thus, they expect a re-

7. The frigates' limitations were exacerbated when they were assigned to aircraft carrier battle group operations. The *Perry* class was conceived and designed to be convoy, replenishment ship, and amphibious group escorts which made their slower speed and less extensive combat suites understandable design decisions.

turn of ten dollars in savings for each one invested now. Half of this seed money is from slowing the F-22 production schedule in the early years and half is already in the production budget for contractor cost-saving incentives. The Air Force will implement incentives in two forms: up to 70% of savings from target costs will be returned to contractors and the Air Force will consider paying outright for a contractor's capital improvements, e.g., new machinery, training or software for advanced fabrication techniques if they create a substantial overall cost savings.

From this discussion, one can easily see why DoD values competitive bidding so highly when it issues contracts and why the consolidation of the defense industrial base has become a cause for concern. Fewer companies competing for contracts translates into higher costs for DoD and, in the worst case, a single-source supplier can name its own price. Currently, only one shipyard in the U.S. can build and overhaul nuclear-powered surface ships so there is only one place where DoD can turn to build nuclear-powered aircraft carriers. The Navy does not have very much leverage over cost—there is no other bidder—so all that remains is to provide performance incentives to reward efficiency on what are fundamentally cost-plus contracts based on costs calculated by the manufacturer. This is not illogical: nuclear-powered aircraft carriers are sufficiently unique and expensive to make competition impractical because there is simply not enough work to keep two shipyards open.

On the other hand, preserving both submarine construction shipyards was the most compelling reason for building the third *Seawolf*-class attack submarine; the network of sub-contractors with their specialized skills would have disappeared before there was enough work to again support a second shipyard. Re-establishing the skills base for a second shipyard would greatly increase the cost of the new attack submarine when it goes into full production. In fact, Congress, DoD, and the Navy carefully distributed the work on the new Virginia-class attack submarines to protect the existence of both shipyards and to maintain at least some form of competition. Similarly, there is great concern whether the loser of the Joint Strike Fighter competition will stay in the military aircraft business.

How much defense industrial consolidation the government should allow and whether DoD should in effect subsidize competitive sources by the way it performs acquisition are contentious issues. If we accept that DoD is going to need unique and expensive weapons systems manufactured by privately-owned companies, we must accept that we are going to pay for them. Whether we can obtain more effectiveness by allowing additional market-driven consolidation that reduces contactor overhead costs or through competition, albeit somewhat artificial at times, is unclear. Our instincts tell us DoD will save money in the short term through consolidation but not in the long term as the number of sole-source suppliers increases and, as a side effect, the competitive spur for innovation is diminished.

CASE STUDY: THE ANALYSIS PHASE–COST
USMC MEDIUM-LIFT REQUIREMENTS: THE V-22 OSPREY AND HELICOPTERS

To measure cost, the Institute for Defense Analyses developed fiscal data for two sets of Marine medium-lift aircraft fleets, each with a 20-year aircraft life cycle. As we discussed at the end of Chapter 3, the first set of alternative fleets (Cost Level I) was based on the Marines' previously stated lift requirements for the assault elements of three brigades. For these larger fleets, DoD would purchase a fleet of 502 V-22s or an equivalent capacity in helicopters for the Marine Corps. The second set of smaller fleets (Cost Level II) was based on the capital investment the Department of the Navy announced it was willing to make when it canceled the V-22 in favor of a replacement helicopter fleet.

The Level I 20-year life cycle cost was $33B (all dollar figures in this case are FY88 constant dollars) and the second-level fleets were based on $24B, the funding level the Department of the Navy was willing to budget to buy a helicopter fleet to support Marine Corps missions. This $24B would buy 356 V-22s. Thus, IDA fixed the 20-year life cycle cost at two levels—$33B and $24B—and then examined the effectiveness of aircraft fleets for each funding level.

Although the mission requirements IDA studied supported the Marines long-term goal of over-the-horizon amphibious assaults, Secretary of Defense Cheney was particularly concerned about near-term (FY91-97) costs in the upcoming Future-Years Defense Program, particularly for his next budget. The Level II costs for the V-22 in this period were $13.1B while the helicopter alternatives ranged from $5.2B to $11.7B. When IDA slowed the production rate of V-22s and delayed full operational capability by two years, the near-term V-22 cost decreased to $7.7B, bringing the V-22 in line with the helicopter alternatives. IDA used relevant costs, e.g., they included the remaining research and development cost for new aircraft and displayed sunk costs before FY91 without incorporating them in future cash flows.

IDA computed the projected aircraft cost for each model with the DoD standard Aircraft RePricing Model and included initial spare parts. They calculated cash flows by multiplying aircraft costs by the annual production rate, including 100 additional aircraft for the Navy and Air Force for the V-22s. IDA based helicopter-operating expenses on the Department of the Navy's Naval Rotary Wing Aircraft Operating and Support Cost-Estimating Model. Since the V-22 is not a helicopter, IDA blended maintenance and component re-work costs from the Navy's Fixed-Wing Model. (All these models are mathematical models that generate cost estimates based on systems characteristics like weight and speed.) IDA's results for Level II are reproduced below:[8]

AIRCRAFT ALTERNATIVE	COST INCURRED FY 1991–97	NET PRESENT VALUE	YEAR BRIGADE ASSAULT
V-22 Nominal Production	**13.1**	**16.3**	**1996**
V-22 Slowed Production	**7.1**	**13.0**	**1998**
New Helicopter	**6.6–8.7**	**11.8–13.0**	**1999**
CH-47M	**5.8–7.9**	**11.6–12.8**	**1997**
CH-60(S)/CH-53E	**8.4–10.5**	**13.6–14.8**	**1996**
CH46E+53E	**8.3–10.4**	**13.3–14.5**	**1998**
Puma/CH-53E	**9.0–11.1**	**13.6–14.7**	**1998**
EH-101/CH-53E	**9.6–11.7**	**14.0–15.2**	**1997**
President's FY90 Budget	**5.2**		

*** Includes new Marine medium and heavy-lift aircraft and 100 Air Force and Navy V-22 variants**

8. Table 12 from the IDA Study (SECRET) *Assessment of Alternatives for the V-22 Assault Aircraft Program (U)* by L. Dean Simmons (Alexandria, VA: IDA, June 1990). This table is unclassified.

> The economic analysis of the V-22 aircraft and the helicopter alternatives was high in validity. IDA used FY 88 constant dollars, adjusted for net present value,[9] to compare the two fleets in a manner consistent with our course concepts—they measured the right kind of cost, in this case near-term cost and life cycle cost. The most important characteristics we look for while assessing reliability are accuracy and whether the results can be replicated. The economic models IDA used provide consistent answers over a wide spectrum of choices, i.e., they are useful for assessing more than the six helicopters and the V-22 alternative fleets. Naturally, contractors tend to be optimistic about their cost forecasts (another circumstance beyond IDA's control) that favor the undeveloped aircraft as well as the V-22. Overall, IDA achieved very good levels of reliability in their economic analysis. The discussions that followed the study's release did not challenge the cost estimates, a convincing indicator of solid economic analysis.
>
> IDA scored well in practicality. They used existing data wherever possible and they were as careful as they could be using estimates. Better data on an unproven technology like the tilt-rotor was simply not available in 1990. They could have enhanced some of their cost estimates by using more than one option to explore a range of cost estimates for the V-22. Overall, we give IDA high marks on the economic analysis in their study.

Summary

Cost is the measure of how many resources we will consume to implement an alternative. It is an essential part of almost every analysis of DoD program and policy options. Increasing effectiveness incurs greater costs: while proponents may talk about benefits and opponents may emphasize cost, they are both actually talking about cost and effectiveness. There are many types of cost and we are most interested in future costs that are relevant to our organization; we discourage executive decision makers from dwelling over sunk costs. In order to compare alternatives across different years, we convert current dollars to constant dollars to remove the effects of inflation.

Executive decision makers must seriously consider the ramifications of reducing short-term costs by reducing procurement rates: they increase average cost, increase total program cost, and delay replacements thereby increasing the age of equipment in the operating forces. The cumulative effect of slowed or reduced procurement cannot be eliminated without direct compensating action—increased production rates and more procurement funding unless we cut force structure.

9. Net Present Value is an accounting technique that attempts to capture the time-value of money beyond inflation which, as we discussed earlier, is the seemingly inevitable rise in prices of goods and services. Assuming the prices are equivalent, one would rather have a television set now rather than ten years from now, i.e., an object purchased in the near future is more valuable to the user than one purchased later. Net Present Value is calculated mathematically like interest or inflation using a discount rate, a rate set by economists to express this future value. We always apply the discount rate to constant (inflation-adjusted) dollars. The discount rate is by its very nature contentious, varies between experts and organizations, and is carefully guarded by business planners because it is key as they decide between investment strategies. Net Present Value calculations are required for all DoD acquisition programs using discount rates set by the President's Office of Management and Budget. For this study, the discount rate was fixed at 10 percent.